Global Mariculture Opportunity Metrics

Final "Mariculture Opportunity" Global Metrics

- **ECONOMIC OPPORTUNITY**
  - prod_ratio: Aquaculture/fisheries production in quantity
  - prod_diversity: Diversity of aquaculture production (weighted by relative production)
  - Q.balance: Export/import ratio in quantity
  - UV.balance: Export/import ratio in value, *per unit production*
- **OPPORTUNITY TO IMPROVE MALNUTRTION**
  - energy_adequacy: index of adequacy of the food supply in terms of calories
  - polyunsatFA: polyunsatured fatty acids
  - calories
  - protein
  - vitaminA
  - iron
  - zinc
- **RELIANCE ON SEAFOOD**: all are percent from seafood/total nutrient intake, and normalized to the 90th percentile country. All countries above the 90th percentile receive a score of 1 (the maximum).
  - polyunsatFA_percentseafood_norm: polyunsatured fatty acids
  - calories_percentseafood_norm
  - protein_percentseafood_norm
  - vitaminA_percentseafood_norm
  - iron_percentseafood_norm
  - zinc_percentseafood_norm
  - mean_reliance: mean of all reliance metrics

Selecting and Joining Relevant Variables

Import the data

```
library(dplyr)
WD <- getwd()

# Economic and malnutrition variables. These are in a couple
# of different tables.  The first has trade balance, energy
# adequacy, and raw nutrient intakes
dat1 <- read.csv(file = paste0(WD, "/data/country_data_2011_full.csv")) %>%
    select(country, Q.balance, UV.balance, energy_adequacy, polyunsatFA,
        calories, protein, vitaminA, iron, zinc)

# this has aquaculture diversity of production
dat2 <- read.csv(paste0(WD, "/data/production_diversity_2014.csv"))

# this has production ratio. Note that this includes
# freshwater aquaculture production, while the diversity
# metric above does not
prod_ratio <- read.csv(paste0(WD, "/data/production_ratio_2014.csv")) %>%
    select(country, prod_ratio)

# reliance data
reliance <- read.csv(paste0(WD, "/data/reliance_norm.csv"))
```

Name conversion key to match countries

```
names_conv <- read.csv(paste0(WD, "/data/nameconversion/name_conversion.csv"),
    stringsAsFactors = F)

# Master names
dat2$country <- names_conv$MASTER[match(dat2$country, names_conv$PDname)]
prod_ratio$country <- names_conv$MASTER[match(prod_ratio$country,
    names_conv$PDname)]
reliance$country <- names_conv$MASTER[match(reliance$country,
    names_conv$nutri)]
```

Join the datasets by country

```
dat.all <- dat1 %>% full_join(dat2, by = "country") %>% distinct(country,
    .keep_all = T) %>% full_join(prod_ratio, by = "country") %>%
    full_join(reliance, by = "country") %>% filter(country !=
    "") %>% distinct(country, .keep_all = T)
```

```
## Warning in full_join_impl(x, y, by$x, by$y, suffix$x, suffix$y): joining
## character vector and factor, coercing into character vector
```

```
# Remove empty rows
all.na.rows <- apply(dat.all, 1, function(x) {
    all(is.na(x[2:length(x)]))
})
dat.all <- dat.all[!all.na.rows, ]
```

Manually remove landlocked countries

```
dat.all <- dat.all[!dat.all$country %in% c("Afghanistan", "Andorra",
    "Armenia", "Austria", "Azerbaijan", "Belarus", "Bhutan",
    "Bolivia", "Botswana", "Burkina Faso", "Burundi", "Central African Republic",
    "Chad", "Czech Republic", "Czechoslovakia", "Ethiopia", "Ethiopia PDR",
    "Hungary", "Kazakhstan", "Kosovo", "Kyrgyzstan", "Laos",
    "Lesotho", "Liechtenstein", "Luxembourg", "Macedonia", "Malawi",
    "Mali", "Moldova", "Mongolia", "Nepal", "Niger", "Paraguay",
    "Rwanda", "San Marino", "Serbia", "Serbia and Montenegro",
    "Slovakia", "South Ossetia", "South Sudan", "Swaziland",
    "Switzerland", "Tajikistan", "Turkmenistan", "Uganda", "Uzbekistan",
    "Vatican City", "Zambia", "Zimbabwe", "Southern Africa",
    "Southern Asia", "Eastern Asia"), ]
```

Reorder the data into categories

```
dat.all <- dat.all %>% select(country, Q.balance, UV.balance,
    prod_diversity, prod_ratio, energy_adequacy, polyunsatFA:zinc,
    calories_percentseafood:mean_reliance)
```

Aggregation and Composite Scores

Norm to 90th percentile country (this is already done for reliance metrics)

```
# normalize to 90th percentile. This means that we'll divide
# everything by the 90th percentile country in the data. All
# countries above this cutoff get forced to 1.
norm_90 <- function(variable) {
    quant90 <- quantile(variable, probs = 0.9, na.rm = T)
```

```
    out <- variable/quant90
    out[out > 1] <- 1
    return(out)
}

# Add new, normalized columns for all variables (except those
# that have already been normalized)
dat.norm <- dat.all %>% mutate_at(vars(Q.balance:zinc), funs(norm = norm_90)) %>%

# reorder again
select(country:iron_percentseafood, Q.balance_norm:zinc_norm,
    calories_percentseafood_norm:iron_percentseafood_norm, mean_reliance)
```

Add aggregated scores for each category, based on 90th percentile normalized scores. For these scores, disregard NA values (although this is an important step and worth revisiting)

```
dat.norm$mean_econ <- rowMeans(select(dat.norm, Q.balance_norm:prod_ratio_norm),
    na.rm = T)
dat.norm$mean_nutrition <- rowMeans(select(dat.norm, energy_adequacy_norm:zinc_norm),
    na.rm = T)
dat.norm$mean_nutrition[is.nan(dat.norm$mean_nutrition)] <- NA
```

A final mariculture opportunity score is calculated as a mean of the other aggregated values. However, because we define the greatest opportunity as a combination of a low economic score (i.e. low value of exports/imports, low production diversity, and low production ratio), a low nutrition score (i.e., low relative nutrient consumption, low energy adequacy), and a HIGH reliance score, we use 1 minus the econ and nutrition scores to do the aggregation, such that a HIGH FINAL SCORE CORRESPONDS TO GREATEST OPPORTUNITY.

```
dat.norm <- dat.norm %>% mutate(econ_opportunity = 1 - mean_econ,
    mean_malnutrition = 1 - mean_nutrition)

# Final score
dat.norm$mariculture_opportunity <- rowMeans(select(dat.norm,
    mean_reliance, econ_opportunity, mean_malnutrition))
```

Write output file

```
write.csv(dat.norm, file = "mariculture_opportunity_metrics_10.23.16.csv",
    row.names = F)
```

Visualizing Mariculture Opportunity

Table of final scores

```
finalmetrics <- select(dat.norm, country, mean_reliance, econ_opportunity:mariculture_opportunity) %>%
    arrange(desc(mariculture_opportunity))

kable(finalmetrics, col.names = c("Country", "Reliance Score",
    "Econ Score", "Malnutrition Score", "Total Score"))
```

Country	Reliance Score	Econ Score	Malnutrition Score	Total Score
Saint Kitts and Nevis	0.9314974	0.9072640	0.5709080	0.8032231
Saint Lucia	0.9375087	0.9173770	0.5361012	0.7969957
Antigua and Barbuda	0.9899554	0.9212179	0.3683934	0.7598555

Country	Reliance Score	Econ Score	Malnutrition Score	Total Score
French Polynesia	1.0000000	0.8347446	0.3889167	0.7412204
Maldives	1.0000000	0.8106656	0.3451024	0.7185893
Sri Lanka	0.8986404	0.6881583	0.4953366	0.6940451
Barbados	0.9429856	0.7648641	0.3401408	0.6826635
Fiji	0.8656354	0.8855979	0.2904068	0.6805467
Bahamas	0.8517195	0.6781933	0.5016280	0.6771803
New Caledonia	0.8916090	0.6542733	0.4021554	0.6493459
Grenada	0.9393811	0.4585031	0.5105430	0.6361424
Jamaica	0.6910116	0.8273644	0.3567382	0.6250381
Malaysia	1.0000000	0.4005251	0.4455257	0.6153503
Ghana	0.6464460	0.9072300	0.2912692	0.6149818
Japan	0.9727668	0.5269265	0.3153231	0.6050055
Brunei	0.7914707	0.5665527	0.4457300	0.6012511
Congo	0.5782802	0.7574377	0.4378613	0.5911931
Iceland	1.0000000	0.5352555	0.2321278	0.5891278
Indonesia	0.7736724	0.4901539	0.4982575	0.5873613
Trinidad and Tobago	0.6103508	0.7031706	0.4081105	0.5738773
Spain	0.8028630	0.6512792	0.2580121	0.5707181
Mauritius	0.5978407	0.7747006	0.3080923	0.5602112
Philippines	0.9101554	0.2982021	0.4653334	0.5578970
Portugal	0.8929744	0.5903484	0.1809313	0.5547514
Dominica	0.6215843	0.6724695	0.3677383	0.5539307
Angola	0.4124815	0.8692102	0.3741381	0.5519433
Thailand	0.7204282	0.3907361	0.4799965	0.5303869
Norway	0.7561596	0.6008464	0.2244646	0.5271568
Finland	0.6119032	0.7275910	0.2406327	0.5267090
Namibia	0.3850644	0.7473323	0.4449790	0.5257919
Gambia	0.6151686	0.6958339	0.2486899	0.5198975
Peru	0.5831696	0.6971505	0.2434330	0.5079177
Cabo Verde	0.3564222	0.7909762	0.3646710	0.5040231
Malta	0.8242521	0.4147953	0.2693707	0.5028060
Libya	0.0873519	0.8521331	0.5657221	0.5017357
Ukraine	0.3840721	0.8076031	0.3078805	0.4998519
Lithuania	0.8593357	0.4719180	0.1292974	0.4868504
Senegal	0.6367321	0.5054095	0.3133896	0.4851771
Cameroon	0.4374582	0.6916445	0.3010939	0.4767322
Belize	0.3609572	0.7315911	0.3252729	0.4726070
Georgia	0.2625102	0.8709691	0.2842472	0.4725755
Benin	0.2338624	0.8445387	0.3367317	0.4717109
Croatia	0.5667705	0.4503276	0.3683301	0.4618094
Tunisia	0.3727051	0.7430724	0.2592171	0.4583315
Sweden	0.4880959	0.6134313	0.2540573	0.4518615
Mozambique	0.1987825	0.6831528	0.4678836	0.4499396
Netherlands	0.4185226	0.7584681	0.1666929	0.4478945
Nigeria	0.3031442	0.8069764	0.2268671	0.4456626
Latvia	0.5480935	0.6100159	0.1778915	0.4453336
South Korea	0.8888275	0.3772696	0.0654624	0.4438531
Russian Federation	0.3717004	0.6694739	0.2800742	0.4404162
Suriname	0.3498204	0.5962174	0.3741270	0.4400549
France	0.6563983	0.5125781	0.1437508	0.4375758
Iraq	0.0427639	0.8847140	0.3763767	0.4346182
New Zealand	0.4499105	0.6754095	0.1765347	0.4339515

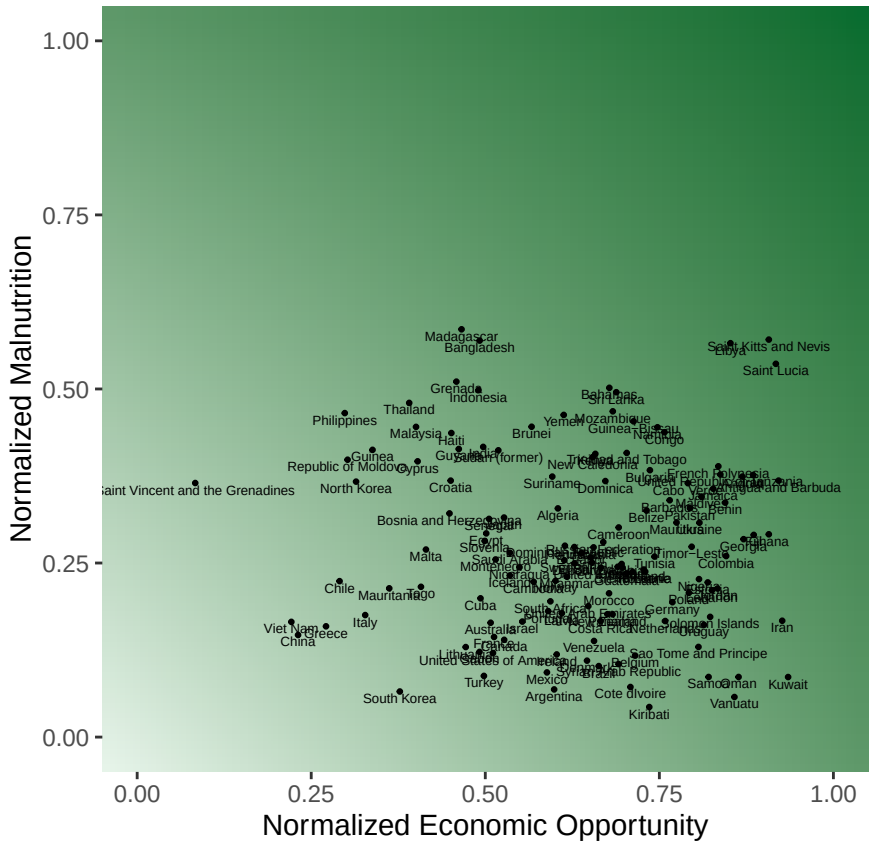
Country	Reliance Score	Econ Score	Malnutrition Score	Total Score
Kuwait	0.2691193	0.9349498	0.0862500	0.4301064
United Arab Emirates	0.4517225	0.6480268	0.1881035	0.4292843
Bulgaria	0.1549748	0.7364720	0.3833291	0.4249253
Lebanon	0.2190800	0.8254865	0.2108830	0.4184831
Estonia	0.2084462	0.8195539	0.2221878	0.4167293
Belgium	0.4162638	0.7153156	0.1170026	0.4161940
Jordan	0.1926183	0.8335821	0.2134149	0.4132051
Madagascar	0.1872590	0.4659072	0.5856738	0.4129467
United Republic of Tanzania	0.0216284	0.8376735	0.3771157	0.4121392
United Kingdom	0.3201966	0.6659010	0.2433577	0.4098184
Morocco	0.3355773	0.6777606	0.2065080	0.4066153
Poland	0.2081262	0.7925132	0.2071722	0.4026038
Iran	0.1105336	0.9264608	0.1670987	0.4013644
Colombia	0.0964265	0.8459641	0.2600099	0.4008002
Denmark	0.4430695	0.6461203	0.1097590	0.3996496
Bangladesh	0.1359289	0.4919373	0.5694684	0.3991115
Guinea-Bissau	0.0290142	0.7129699	0.4534772	0.3984871
Cyprus	0.3810385	0.4028475	0.3960706	0.3933189
Germany	0.1784457	0.7688190	0.1937474	0.3803373
Pakistan	0.0160825	0.7940486	0.3287521	0.3796277
Australia	0.4466988	0.5076946	0.1642275	0.3728737
Panama	0.2373410	0.6828902	0.1762307	0.3654873
Ireland	0.3601446	0.6025999	0.1187307	0.3604917
Albania	0.1446012	0.6555298	0.2725017	0.3575443
Kenya	0.0046901	0.6580692	0.4068187	0.3565260
Romania	0.1015987	0.7297097	0.2376531	0.3563205
Algeria	0.1329820	0.6043120	0.3284555	0.3552498
Uruguay	0.0855315	0.8140566	0.1611132	0.3535671
Canada	0.3876994	0.5271437	0.1397159	0.3515197
Dominican Republic	0.1600275	0.6143674	0.2748430	0.3497460
Guinea	0.2744100	0.3380699	0.4125437	0.3416745
Ecuador	0.1222166	0.6381540	0.2644542	0.3416083
Republic of Moldova	0.3212455	0.3022332	0.3983781	0.3406189
Haiti	0.1331513	0.4512893	0.4367089	0.3403832
Venezuela	0.2265322	0.6561832	0.1380737	0.3402631
El Salvador	0.1095814	0.6532134	0.2505140	0.3377696
Egypt	0.2156992	0.5013694	0.2925547	0.3365411
Syrian Arab Republic	0.2076318	0.6915469	0.1048557	0.3346781
Slovenia	0.2091562	0.4992405	0.2817381	0.3300450
Israel	0.2628495	0.5532144	0.1658977	0.3273205
Saint Vincent and the Grenadines	0.5330687	0.0834166	0.3648921	0.3271258
Montenegro	0.2049892	0.5149068	0.2551231	0.3250064
India	0.0602174	0.4969912	0.4167855	0.3246647
United States of America	0.3293263	0.5110624	0.1207291	0.3203726
Italy	0.4563623	0.3275345	0.1752411	0.3197127
Saudi Arabia	0.1580289	0.5353892	0.2647299	0.3193827
Guatemala	0.0168006	0.7030972	0.2350956	0.3183311
Honduras	0.0418777	0.6278888	0.2729544	0.3142403
Sudan (former)	0.0089859	0.5187587	0.4118816	0.3132087
Costa Rica	0.1070413	0.6656706	0.1664442	0.3130520
Djibouti	0.0553802	0.6280288	0.2495672	0.3109921
South Africa	0.1324363	0.5935550	0.1949430	0.3069781

Country	Reliance Score	Econ Score	Malnutrition Score	Total Score
Nicaragua	0.1073354	0.5491695	0.2438359	0.3001136
Bosnia and Herzegovina	0.1140383	0.4486162	0.3212489	0.2946345
China	0.4918403	0.2311059	0.1466267	0.2898576
Brazil	0.0792715	0.6630047	0.1019652	0.2814138
Mexico	0.1391135	0.5885514	0.0928803	0.2735151
Cuba	0.0571851	0.4931591	0.1993121	0.2498854
Argentina	0.0786807	0.5989090	0.0684462	0.2486786
Greece	0.2965982	0.2712393	0.1590691	0.2423022
Mauritania	0.1481421	0.3620748	0.2136723	0.2412964
Turkey	0.1332645	0.4980507	0.0878710	0.2397287
Chile	0.2010680	0.2907318	0.2239595	0.2385865
Aruba	NA	0.9801294	NA	NA
Bahrain	NA	0.6693392	NA	NA
Bermuda	NA	0.8421292	NA	NA
Cote dIvoire	NA	0.7084548	0.0719424	NA
Cambodia	NA	0.5694899	0.2230216	NA
Cayman Islands	NA	0.8609236	NA	NA
Hong Kong	NA	0.4835057	NA	NA
Macao	NA	0.7503508	NA	NA
Comoros	NA	0.4987771	NA	NA
Democratic Republic of the Congo	NA	0.7733062	NA	NA
Cook Islands	NA	0.8996180	NA	NA
Cura cao	NA	0.3845223	NA	NA
Equatorial Guinea	NA	0.9148909	NA	NA
Eritrea	NA	0.5754407	NA	NA
Falkland Islands	NA	0.6664947	NA	NA
Faroe Islands	NA	0.6583578	NA	NA
French Guiana	NA	0.8980387	NA	NA
Gabon	NA	0.4916794	0.1223022	NA
Greenland	NA	0.7832520	NA	NA
Guadeloupe	NA	0.8346213	NA	NA
Guam	NA	0.5850754	NA	NA
Guyana	NA	0.4619555	0.4137999	NA
Kiribati	NA	0.7355357	0.0431655	NA
North Korea	NA	0.3144168	0.3669065	NA
Liberia	NA	0.6902241	0.2446043	NA
Marshall Islands	NA	0.8429918	NA	NA
Martinique	NA	0.7406403	NA	NA
Mayotte	NA	0.7492910	NA	NA
Micronesia	NA	0.6374852	NA	NA
Myanmar	NA	0.6173927	0.2302158	NA
Netherlands Antilles	NA	0.7064149	NA	NA
Oman	NA	0.8638049	0.0863309	NA
Palau	NA	0.6034619	NA	NA
Palestine	NA	0.8765766	NA	NA
Papua New Guinea	NA	0.8736820	NA	NA
Qatar	NA	0.7247069	NA	NA
Reunion	NA	0.8541057	NA	NA
Saint Helena	NA	0.4874184	NA	NA
Samoa	NA	0.8207493	0.0863309	NA
Sao Tome and Principe	NA	0.8062150	0.1294964	NA
Seychelles	NA	0.6451836	NA	NA

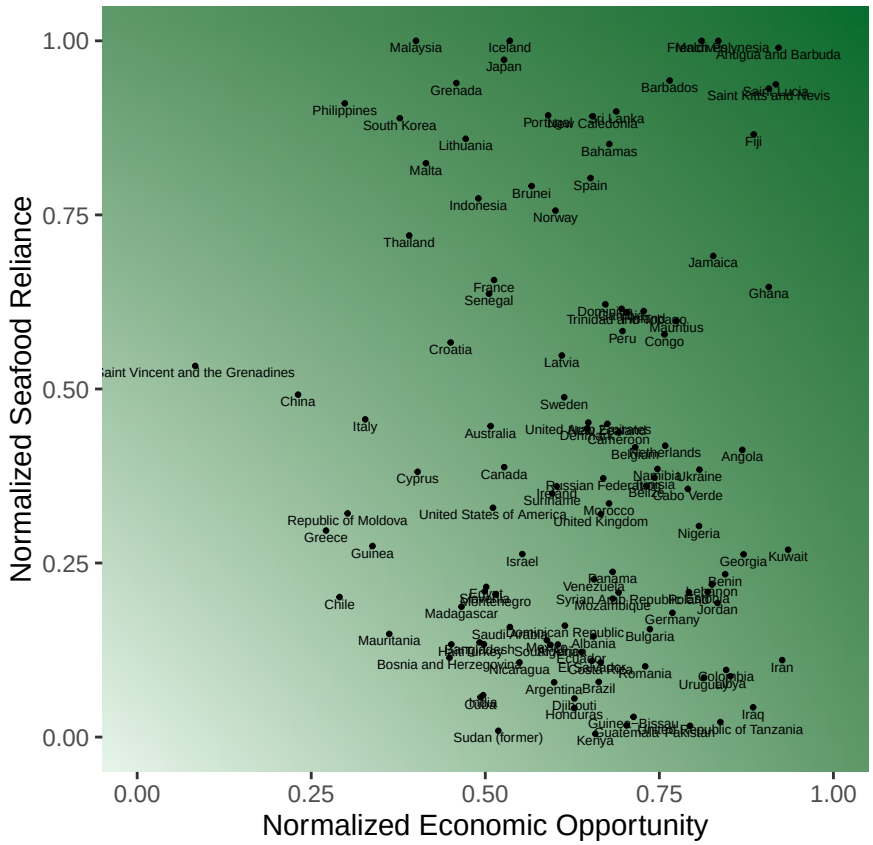
Country	Reliance Score	Econ Score	Malnutrition Score	Total Score
Sierra Leone	NA	0.7115266	0.2374101	NA
Singapore	NA	0.4102857	NA	NA
Solomon Islands	NA	0.8229851	0.1726619	NA
Somalia	NA	0.3891780	NA	NA
Saint Pierre and Miquelon	NA	0.7751219	NA	NA
Sudan	NA	0.4981707	NA	NA
Taiwan	NA	0.5715001	NA	NA
Timor-Leste	NA	0.7964578	0.2733813	NA
Togo	NA	0.4076330	0.2158273	NA
Tonga	NA	0.8822532	NA	NA
Turks and Caicos Islands	NA	0.7964610	NA	NA
Tuvalu	NA	0.7070471	NA	NA
USSR	NA	0.3361177	NA	NA
Vanuatu	NA	0.8578349	0.0575540	NA
Viet Nam	NA	0.2214521	0.1654676	NA
Yemen	NA	0.6126847	0.4627168	NA
Yugoslavia SFR	NA	0.3624308	NA	NA
Puerto Rico	NA	1.0000000	NA	NA
Nauru	NA	0.9996367	NA	NA
Northern Mariana Islands	NA	0.9906922	NA	NA
Bonaire	NA	1.0000000	NA	NA
Zanzibar	NA	0.4449259	NA	NA

Scatterplots of countries along opportunity axes

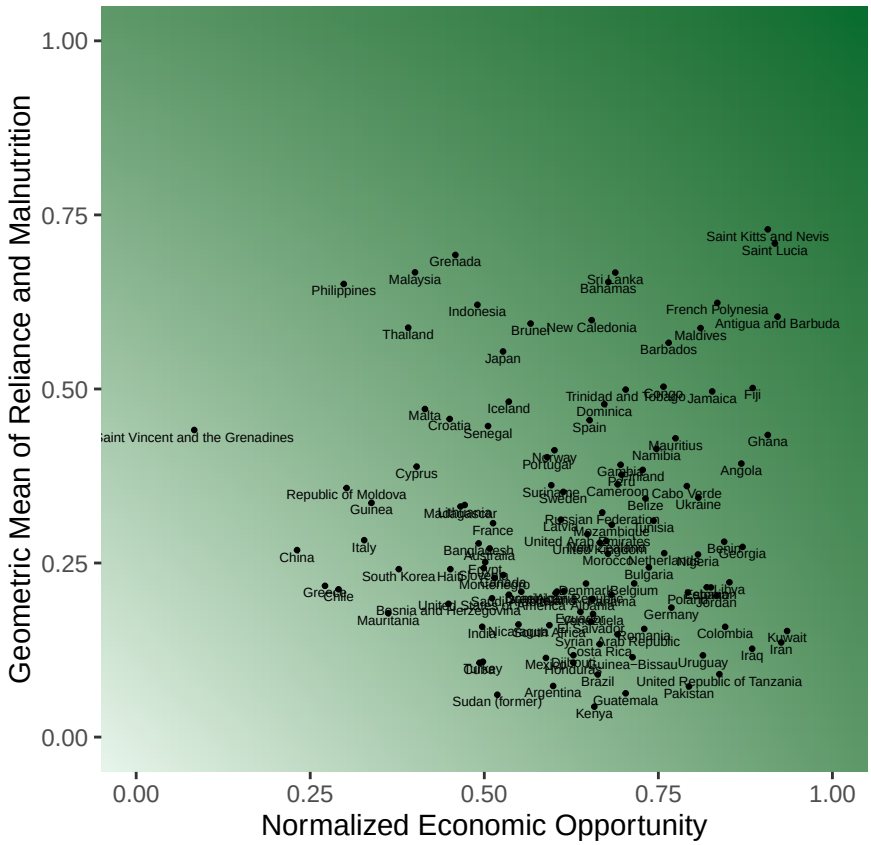
```
# Table of final backgrounds Colors for background
library(grid)
library(scales)
library(ggplot2)



# Background raster
m <- tcrossprod(seq(1, 2, length = 50), seq(2, 1, length = 50))
pal <- gradient_n_pal(c("#086D30", "#E6F4E9"), values = c(1,
    4))
cols <- matrix(pal(m), nrow(m))
rast <- rasterGrob(cols, x = unit(0.5, "npc"), y = unit(0.5,
    "npc"))

# econ vs. malnutrition
ggplot(dat.norm, aes(x = econ_opportunity, y = mean_malnutrition)) +
    # add gradient background
annotation_custom(rast, xmin = -Inf, xmax = Inf, ymin = -Inf,
    ymax = Inf) + geom_point(size = 0.5) + geom_text(aes(label = country),
    size = 1.8, vjust = 1.2) + xlab("Normalized Economic Opportunity") +
    ylab("Normalized Malnutrition") + coord_fixed(xlim = c(0,
    1), ylim = c(0, 1))
```




```
# econ vs. reliance
ggplot(dat.norm, aes(x = econ_opportunity, y = mean_reliance)) +
    # add gradient background
annotation_custom(rast, xmin = -Inf, xmax = Inf, ymin = -Inf,
    ymax = Inf) + geom_point(size = 0.5) + geom_text(aes(label = country),
    size = 1.8, vjust = 1.2) + xlab("Normalized Economic Opportunity") +
    ylab("Normalized Seafood Reliance") + coord_fixed(xlim = c(0,
    1), ylim = c(0, 1))
```




```
# econ vs. (reliance*malnutrition)
dat.norm <- dat.norm %>% mutate(reliance_mal = sqrt(mean_reliance *
    mean_malnutrition))
ggplot(dat.norm, aes(x = econ_opportunity, y = reliance_mal)) +
    # add gradient background
annotation_custom(rast, xmin = -Inf, xmax = Inf, ymin = -Inf,
    ymax = Inf) + geom_point(size = 0.5) + geom_text(aes(label = country),
    size = 1.8, vjust = 1.2) + xlab("Normalized Economic Opportunity") +
    ylab("Geometric Mean of Reliance and Malnutrition") + coord_fixed(xlim = c(0,
    1), ylim = c(0, 1))
```


Geometric Mean of Reliance and Malnutrition
Normalized Economic Opportunity
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Saint Kitts and Nevis
Saint Lucia
Grenada
Malaysia
Philippines
Sri Lanka
Bahamas
Indonesia
French Polynesia
Antigua and Barbuda
Thailand
Brunei
New Caledonia
Maldives
Barbados
Japan
Trinidad and Tobago
Jamaica
Fiji
Iceland
Malta
Croatia
Senegal
Dominica
Spain
Saint Vincent and the Grenadines
Mauritius
Ghana
Namibia
Portugal
Angola
Cyprus
Republic of Moldova
Guinea
Sweden
Cameroon
Cabo Verde
Belize
Ukraine
France
Italy
China
Georgia
South Korea
Bulgaria
Chile
Germany
Mauritania
Colombia
Kuwait
Iran
Iraq
Costa Rica
Uruguay
Brazil
United Republic of Tanzania
Pakistan
Argentina
Guatemala
Sudan (former)
Kenya